Evaluation of GCM simulated Radiation Budgets at Surface, TOA, and Atmosphere using CERES-BSRN observations.

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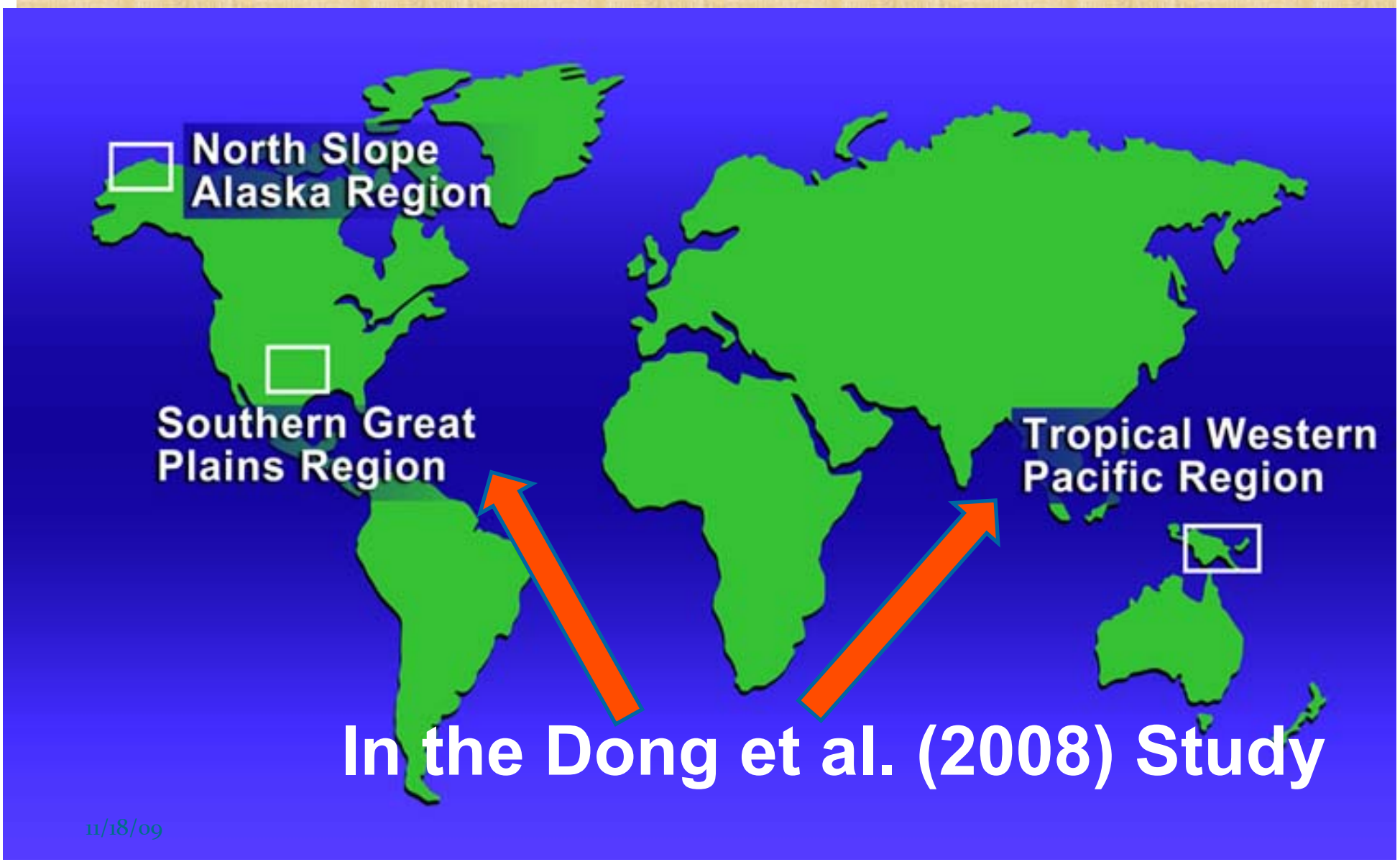
Motivation



In the Dong et al. (2008) Study

TWP sites

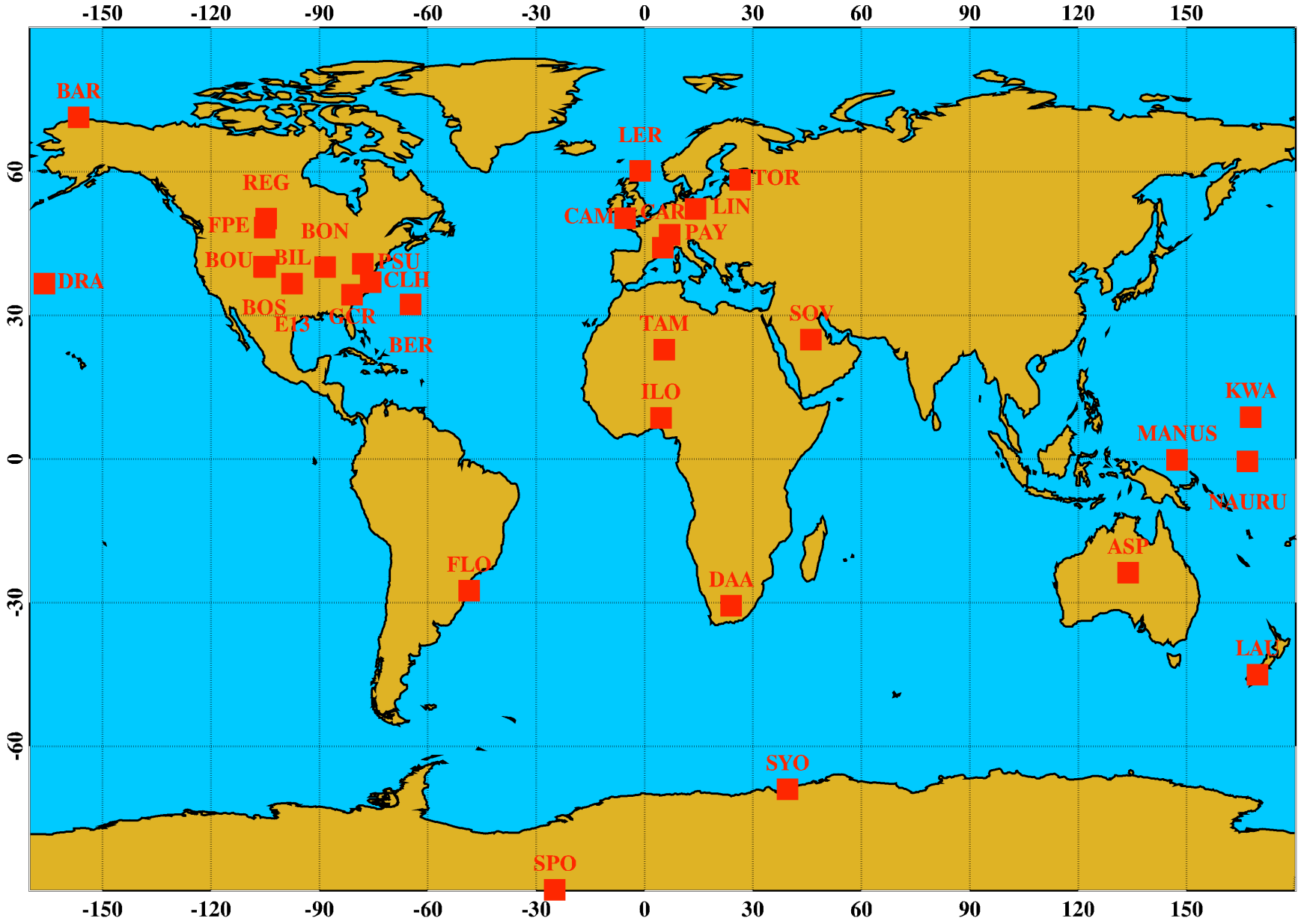
Samples	τ	R_{TOA}	A_{SFC}	A_{COL}
229 for τ>15	36	0.575	0.129	0.296
119 for τ>30	50	0.627	0.093	0.280
70 for τ>40	61	0.650	0.075	0.275
45 for τ>50	70	0.667	0.070	0.263
29 for τ>60	78	0.682	0.051	0.267
17 for τ>70	88	0.693	0.035	0.272
10 for τ>80	96	0.702	0.030	0.268

SGP site

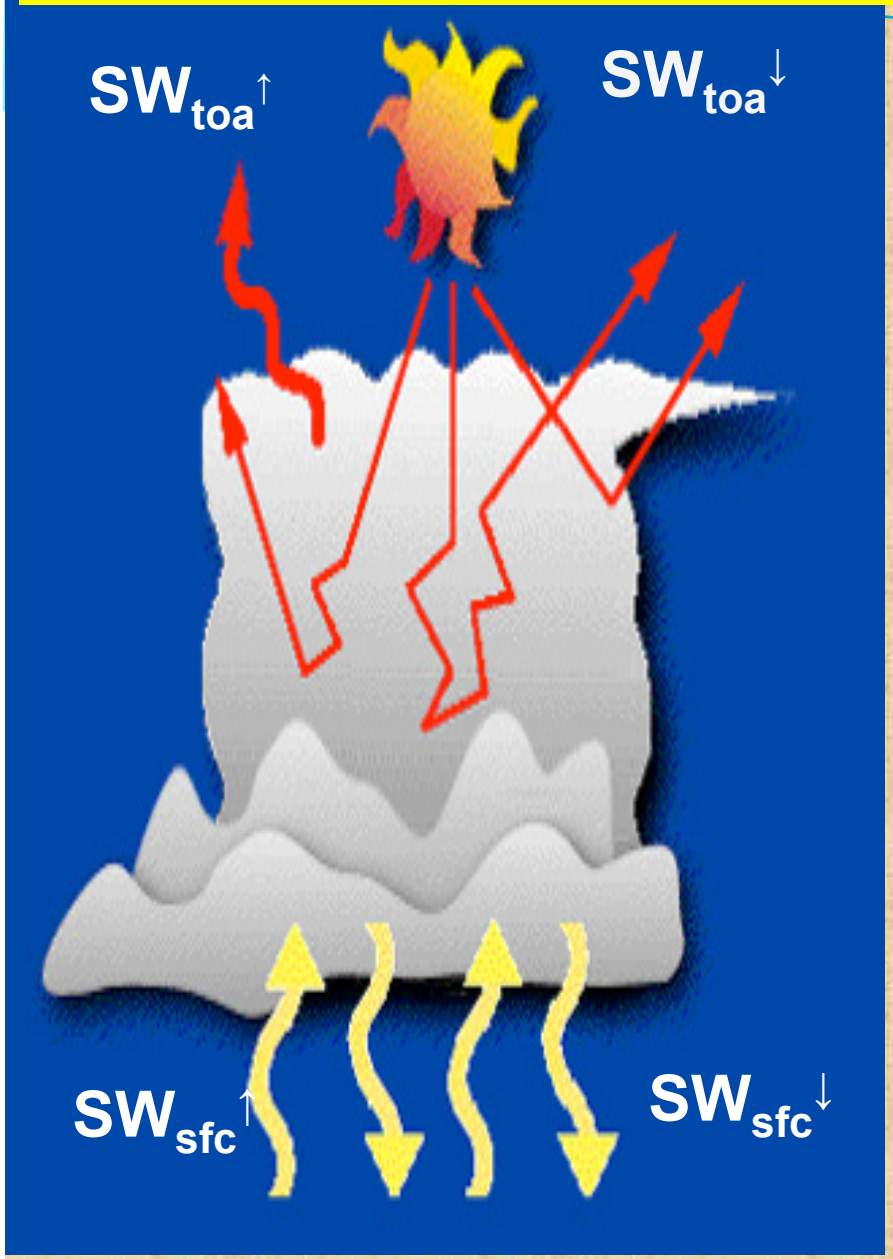
Samples	τ	R_{TOA}	A_{SFC}	A_{COL}
182 for τ>15	37	0.594	0.121	0.285
108 for τ>30	48	0.625	0.096	0.279
67 for τ>40	57	0.642	0.083	0.275
35 for τ>50	68	0.661	0.064	0.275
16 for τ>60	82	0.675	0.058	0.266
10 for τ>70	93	0.689	0.047	0.264
8 for τ>80	97	0.693	0.037	0.270

R_{TOA} increases and A_{SFC} decreases with increased tau. A_{COL} at TWP is 1.1% more than that at SGP, but they converge to the same value (~0.27) at tau > 50.

35 Selected Global BSRN Stations



Using CERES-BSRN data and GCM to study:



1) How much SW **transmits to the Earth surface?**

$T_{SFC}=SW_{SFC}^{\downarrow}/SW_{TOA}^{\downarrow}$

2) How much SW **is reflected back to space?**

$R_{TOA}=SW_{TOA}^{\uparrow}/SW_{TOA}^{\downarrow}$

3) How much SW **is absorbed by atmospheric column**

$A_{COL}=1-R_{TOA}-T_{SFC}$
$+ SW_{SFC}^{\uparrow}/SW_{TOA}^{\downarrow}$

Data and Methods

Time period: March 2000-December 2004

Location: Over the 35 selected BSRN sites

Method: Monthly means for clear- and all-sky conditions

Surface and Satellite data

- **Satellite data: use the closest FOV data to the BSRN stations**
- **BSRN data: 1-hr average of SW-down flux centered at each TERRA/AQUA overpass**
- **The atmospheric column absorption was inferred from CERES TOA albedo and BSRN surface absorption**

$$A_{COL} = 1 - R_{TOA} - A_{SFC}$$

ECHAM5-HAM

Global climate Model ECHAM5-HAM, developed at Max Planck Institute for Meteorology, Hamburg, and installed and simulated at ETH Zurich

- **Research version with sophisticated aerosol and cloud microphysics scheme, including sulfate, black carbon, particulate organic matter, sea salt and dust, prognostic size distribution, composition, mixing state (Stier et al. 2005, ACP, Lohmann 2007 ACP)**
- **Transient simulation with time dependent aerosol and aerosol precursor emission histories, greenhouse gases, volcanic aerosol. prescribed SST and sea-Ice variations according to observations.**
- **Horizontal resolution T106 (~ 1° x 1°), 31 vertical layers**
- **Maximum cloud overlap is assumed for contiguous cloud layers, random overlap else**
- **Radiation: RRTM Mlawer et al. (1997) for Longwave, Morcrette (1991) for Shortwave**
- **Mass flux scheme (Tiedtke, 1989) for cumulus convection with modifications for penetrative convection according to Nordeng (1994).**

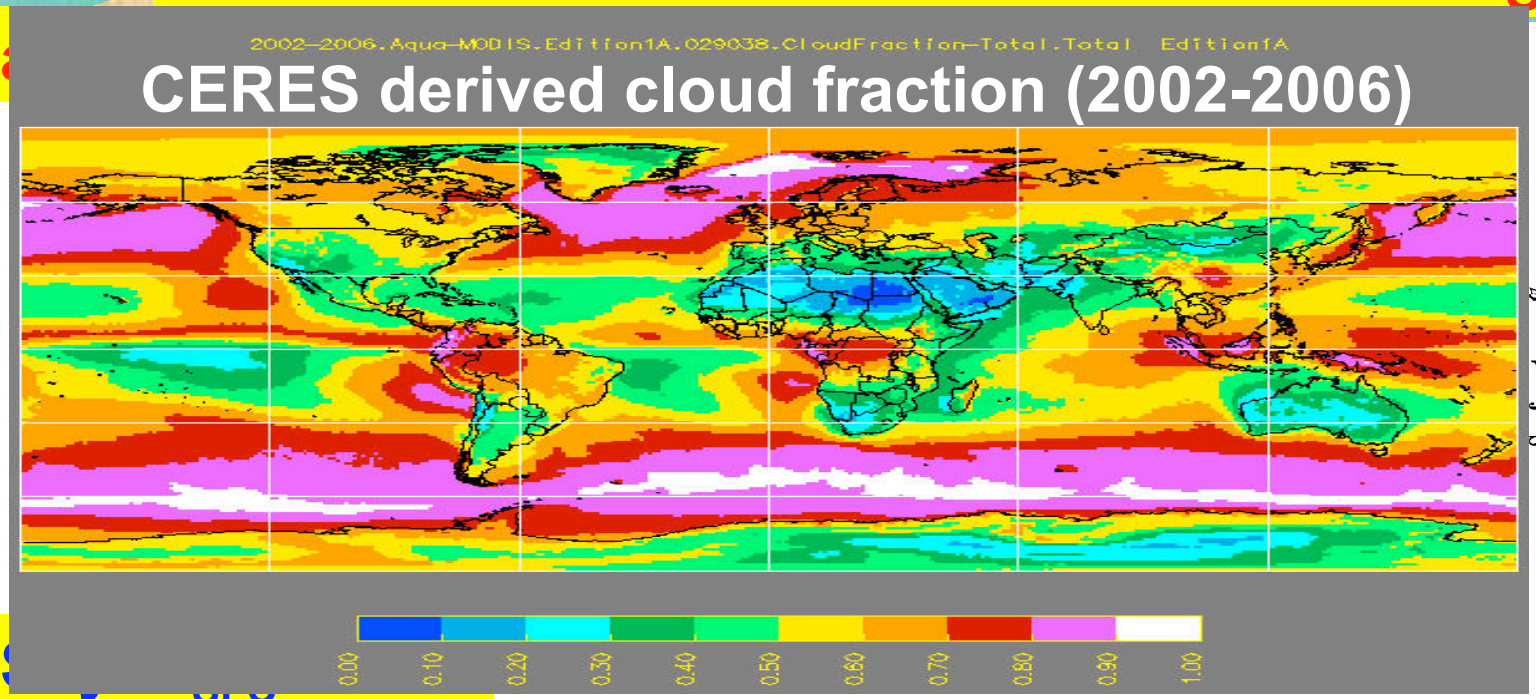
Goals of this study

1. To evaluate the ECHAM5 simulated Surface transmission T_{SFC}, TOA albedo R_{TOA} and Atmospheric Column absorption A_{COL} using CERES-BSRN data

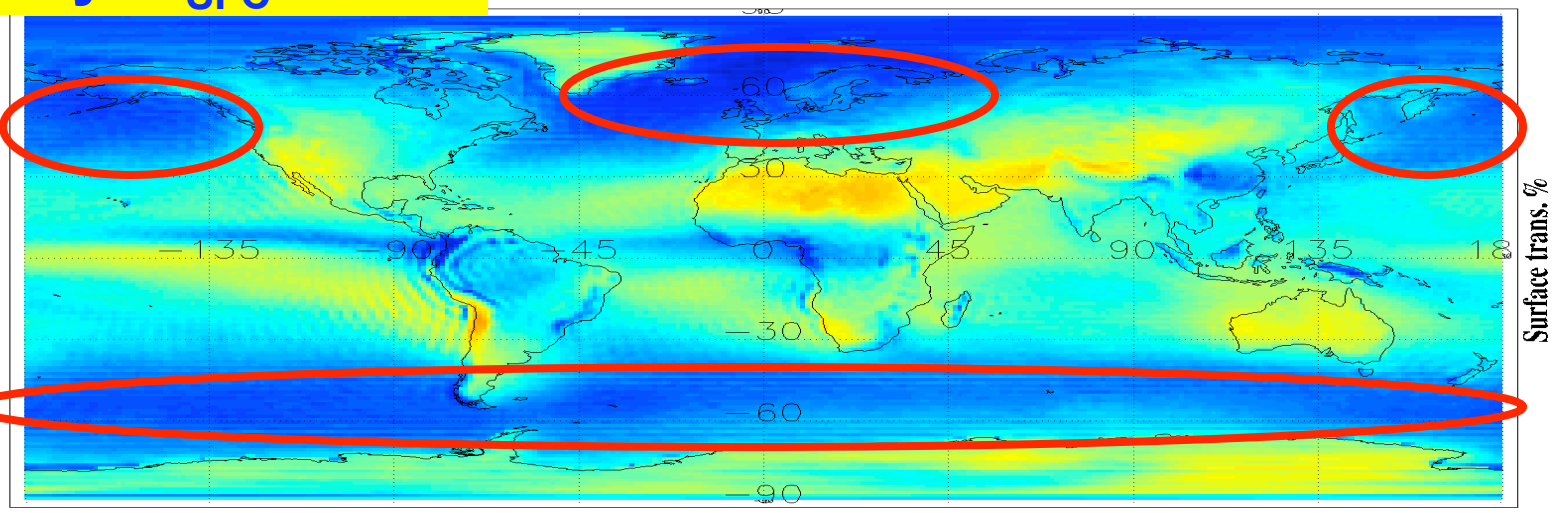
2. To study the seasonal variations of T_{SFC}, R_{TOA} and A_{COL} at different Climate regimes and surface types?

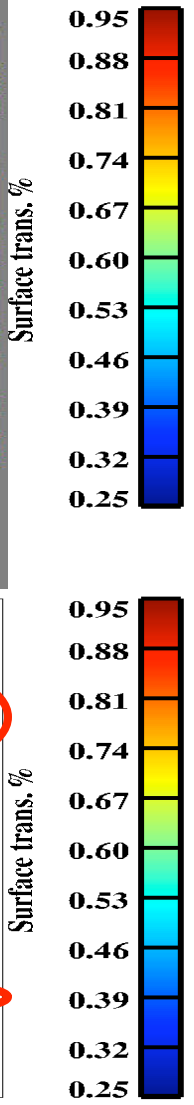
Modeled Surface Transmission T_{SFC}

Clea



All S

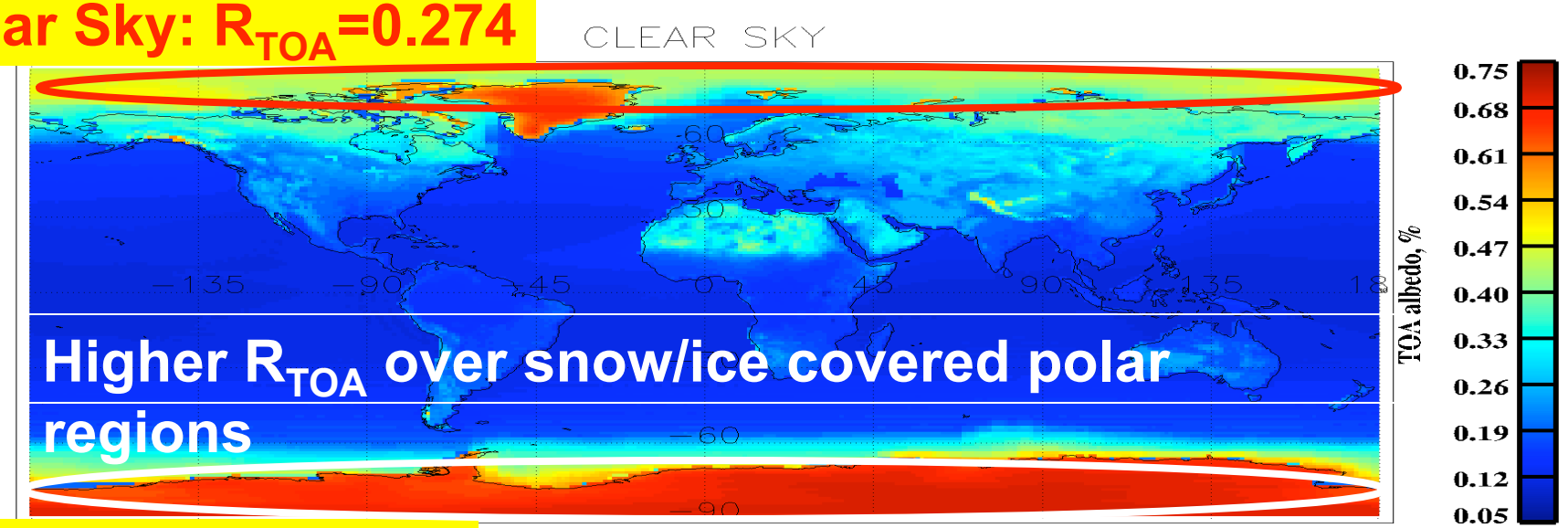




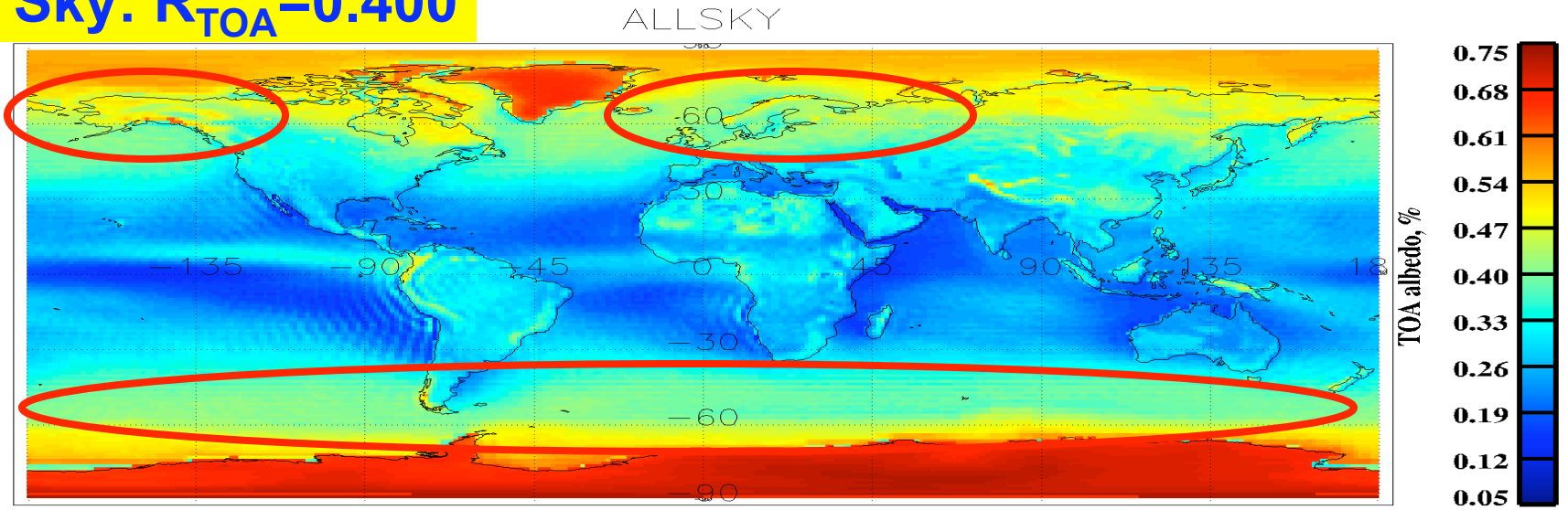
The lower T_{SFC} under all-sky conditions is certainly related to clouds

Modeled TOA Albedo R_{TOA}

Clear Sky: R_{TOA}=0.274



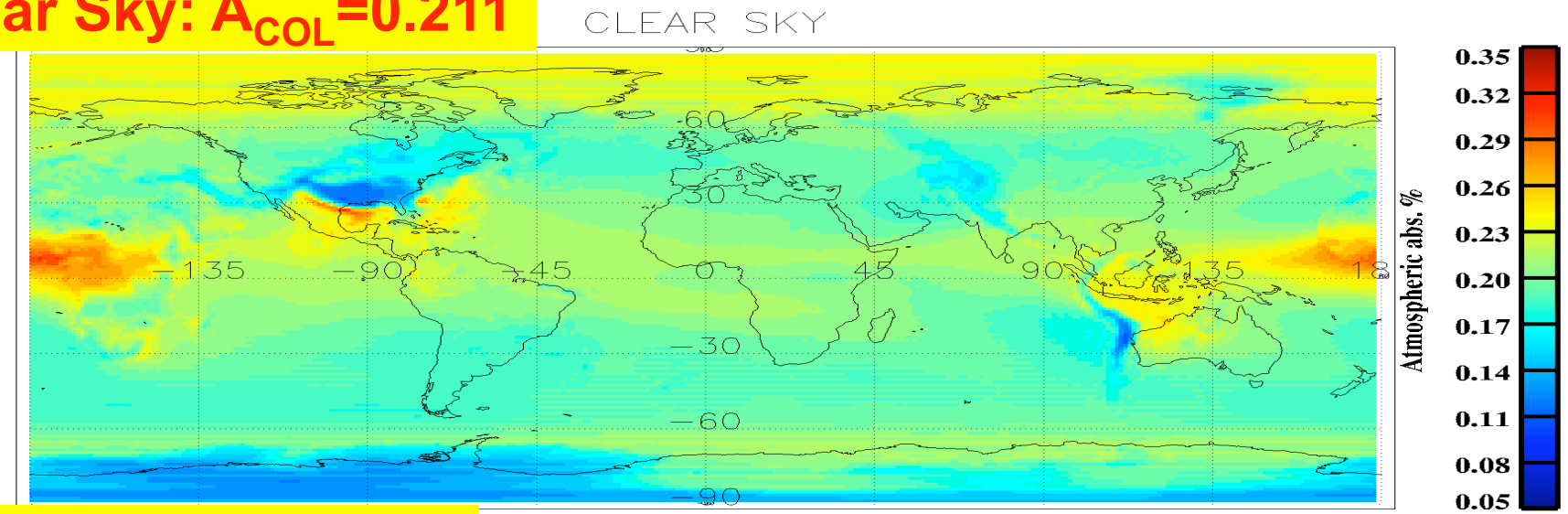
All Sky: R_{TOA}=0.400



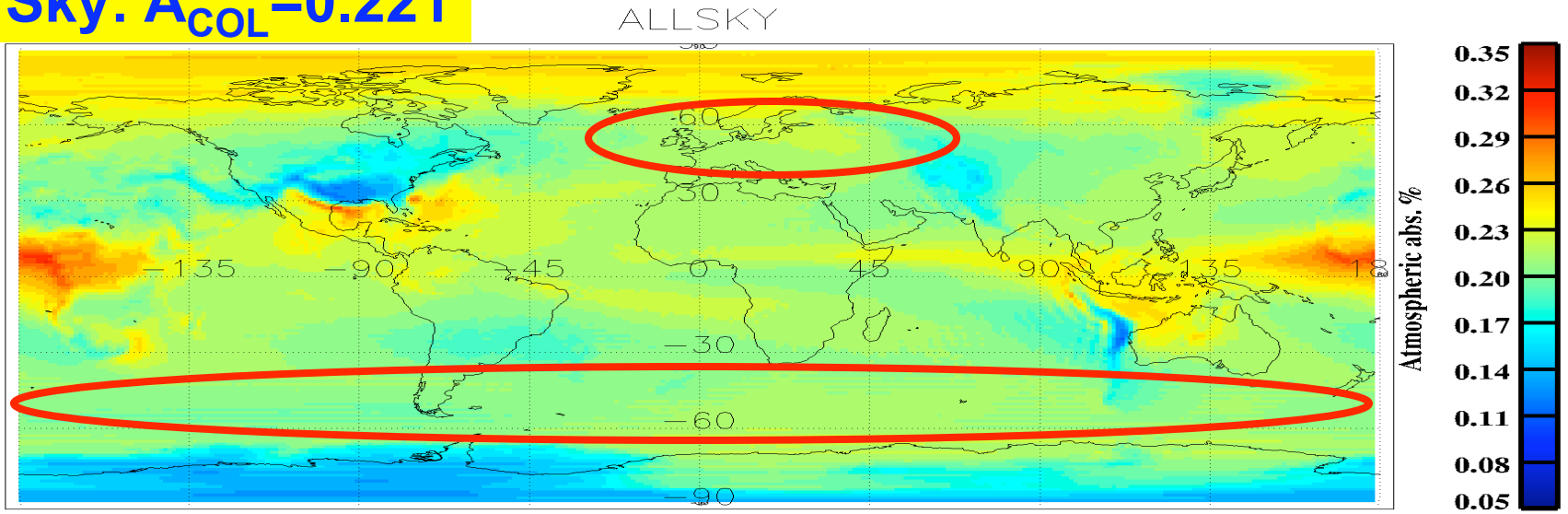
All-sky higher R_{TOA} , corresponding to lower T_{SFC}, is resulted from clouds

Modeled Atmospheric Column Absorption A_{COL}

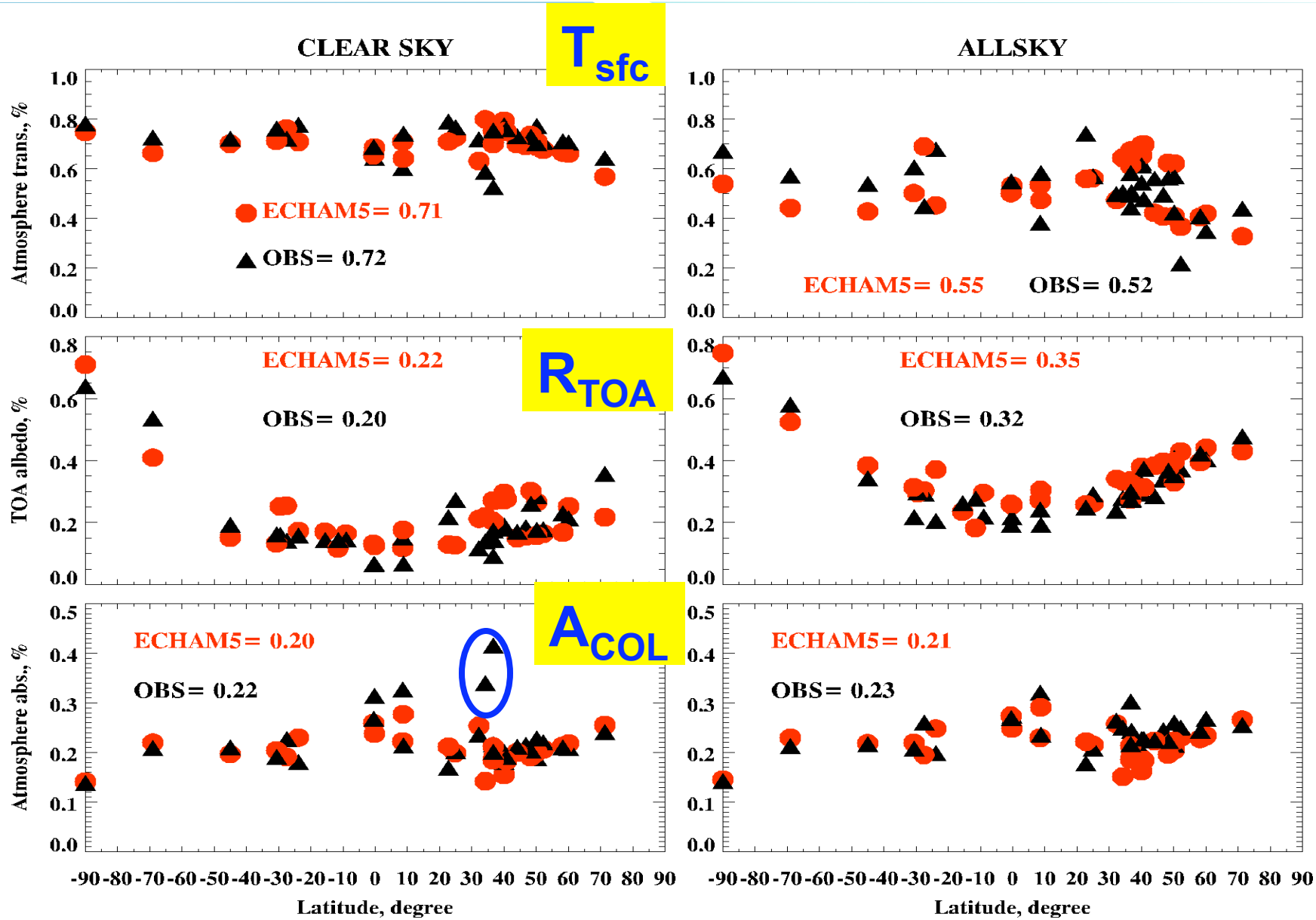
Clear Sky: A_{COL}=0.211



All Sky: A_{COL}=0.221

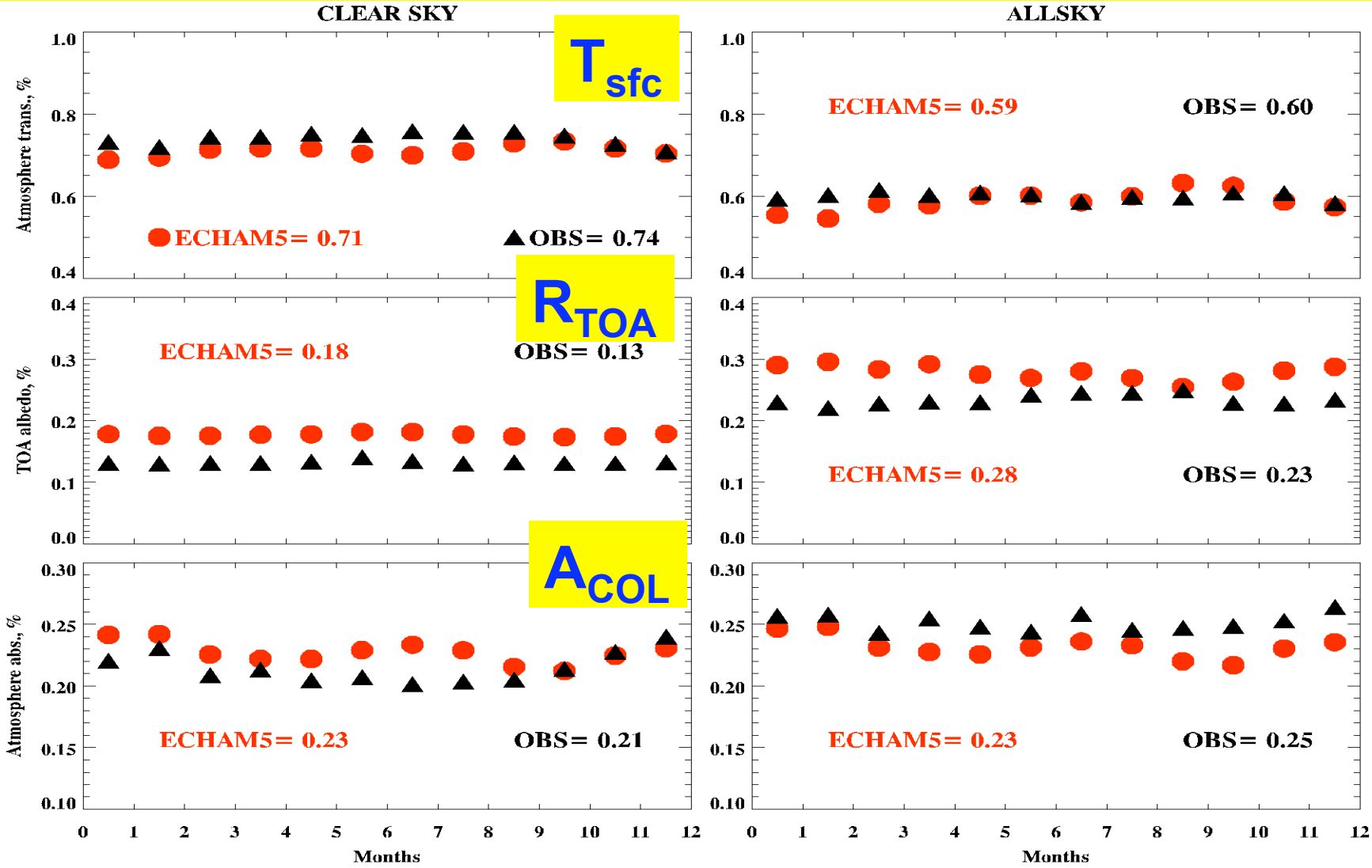


There is NO significant difference between clear and all skies, only a couple percent higher under cloudy regions



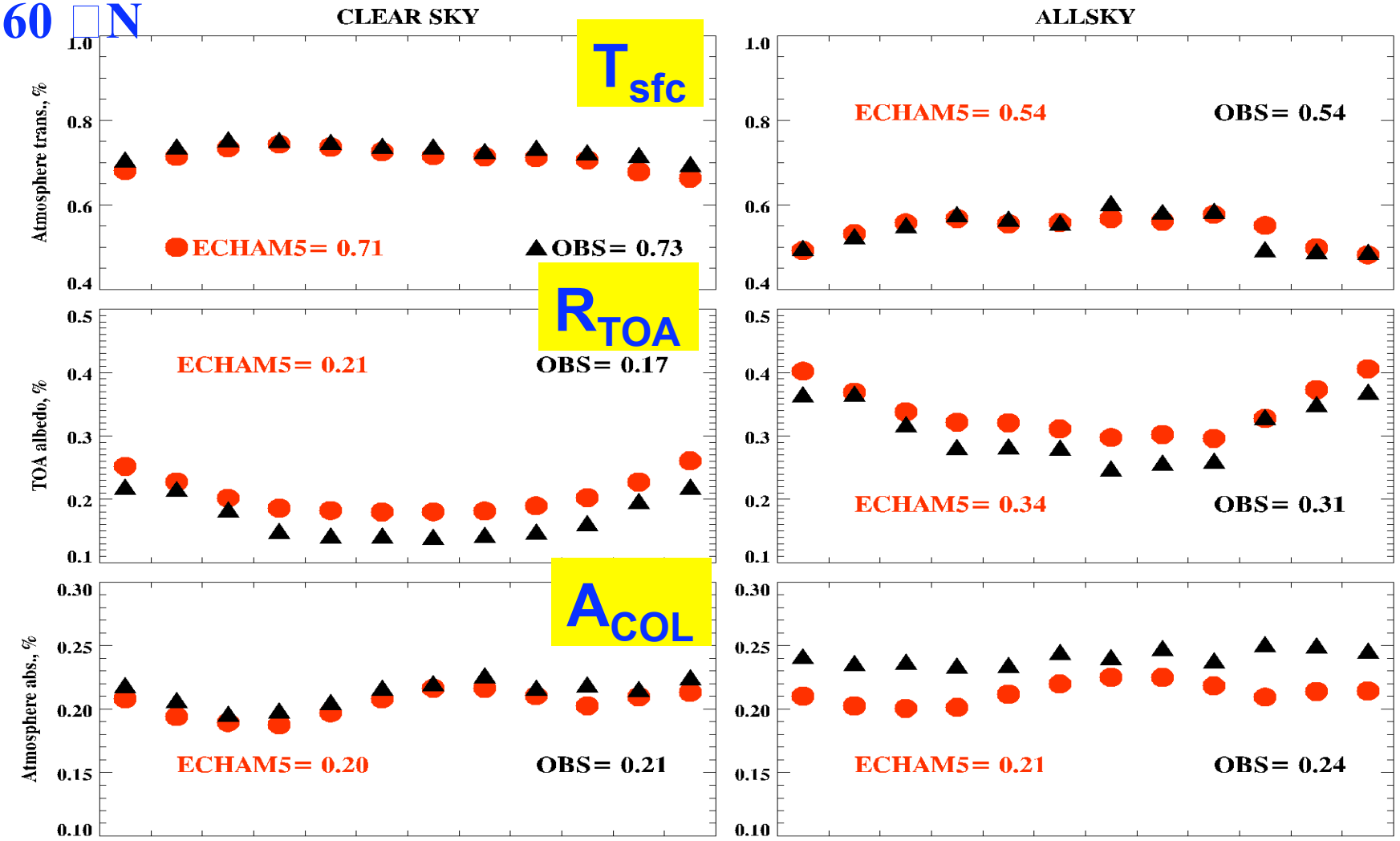
On average, GCM simulations agree with observations within 1-3%, but there are some discrepancies in a few stations, which lead us to do the following analyses.

Seasonal Variation over Tropical regions (30 ºS to 30 ºN)



T_{SFC} and R_{TOA} have negligible seasonal variations, A_{COL} has weak.
Clear-sky: Model may overestimate water vapor and aerosol effects
All-sky: Large differences between model and data due to clouds

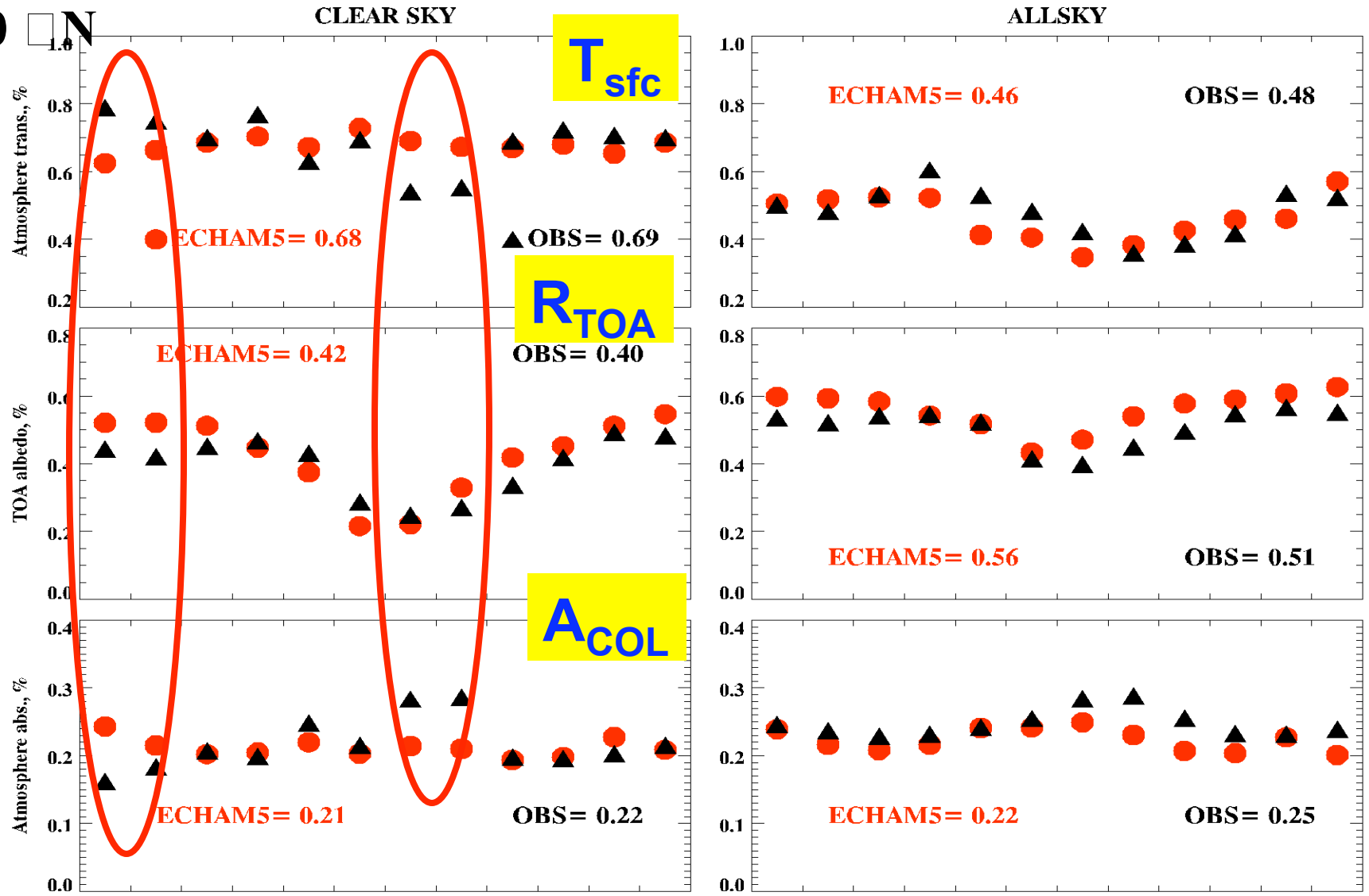
Seasonal Variation over Mid-latitude: 30 □S to 60 □S and 30 □N to 60 □N



Seasonal variations are strong due to large seasonal variation in PWV, SZA, & R_{SFC}

Modeled T_{SFC} agrees well with data for both clear and all-sky, but modeled R_{TOA} overestimated by 3-4%, ➔A_{COL} 1-3% less.

Seasonal Variation over Polar regions: 60 □S to 90 □S and 60 □N to 90 □N



Over Polar regions, it is the mixed effect of changes in cloud and highly reflective surface. Overall, modeled results agree within 5% with large difference during winter and summer months.

Summary by Climate regimes

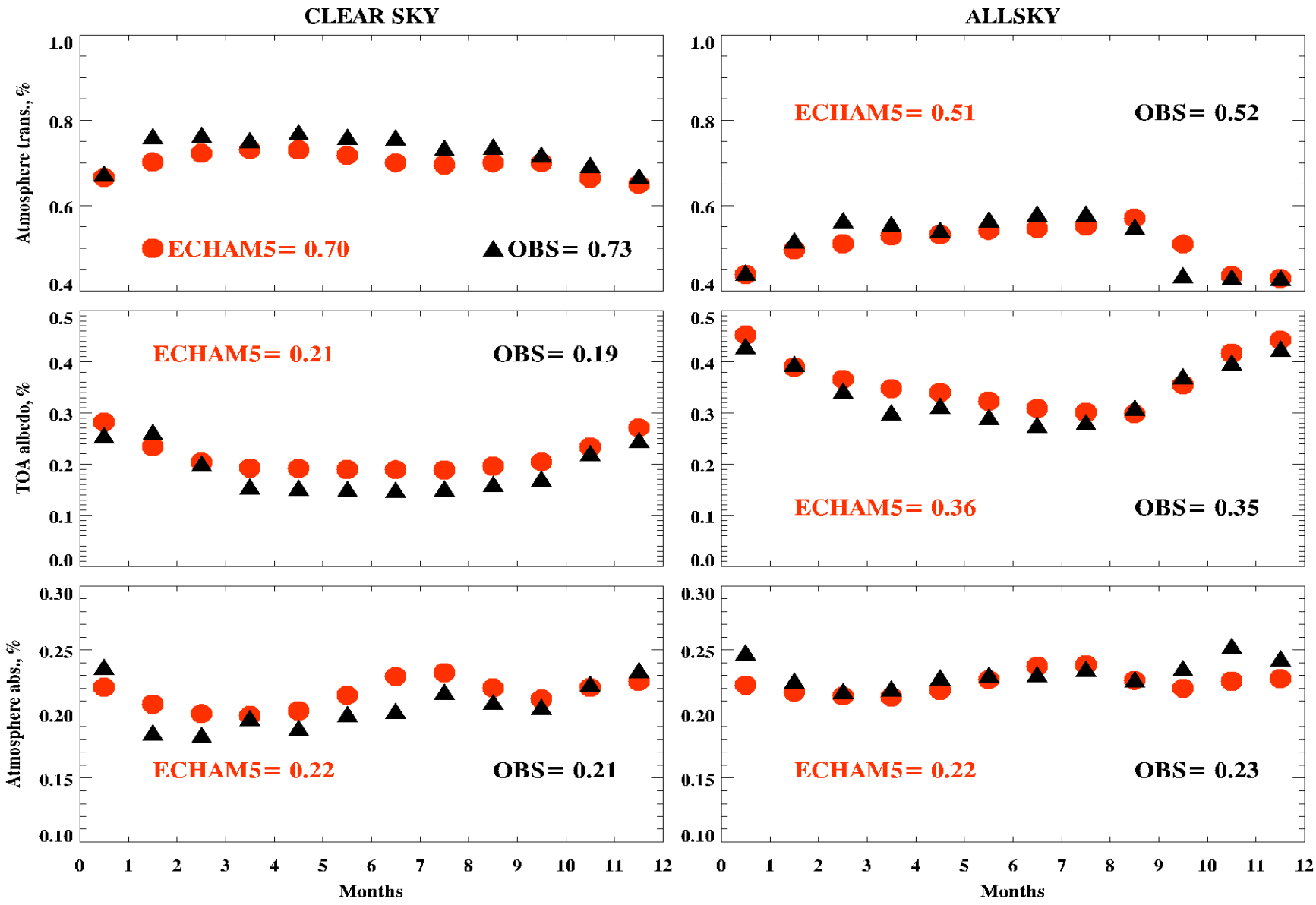
Clear Sky

Region	T_{SFC} Model	T_{SFC} Obs.	R_{TOA} Model	R_{TOA} Obs.	A_{COL} Model	A_{COL} Obs.
Tropical	0.71	0.74	0.18	0.13	0.23	0.22
Mid-lat.	0.71	0.73	0.21	0.17	0.20	0.21
Polar	0.68	0.69	0.42	0.40	0.21	0.22

All Sky

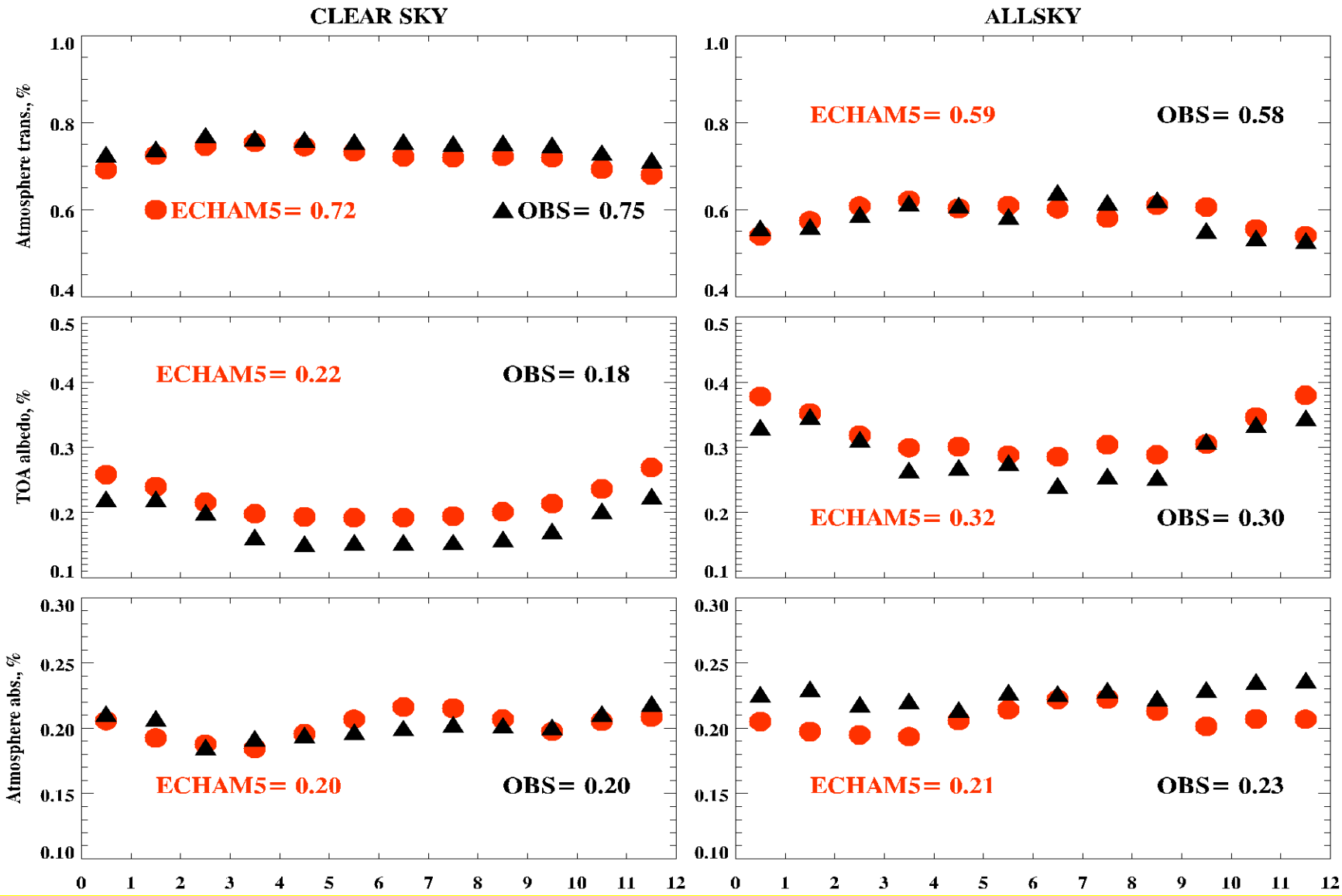
Region	T_{SFC} Model	T_{SFC} Obs.	R_{TOA} Model	R_{TOA} Obs.	A_{COL} Model	A_{COL} Obs.
Tropical	0.59	0.60	0.28	0.23	0.23	0.25
Mid-lat.	0.54	0.54	0.34	0.31	0.21	0.24
Polar	0.46	0.48	0.56	0.51	0.22	0.25

Over Land



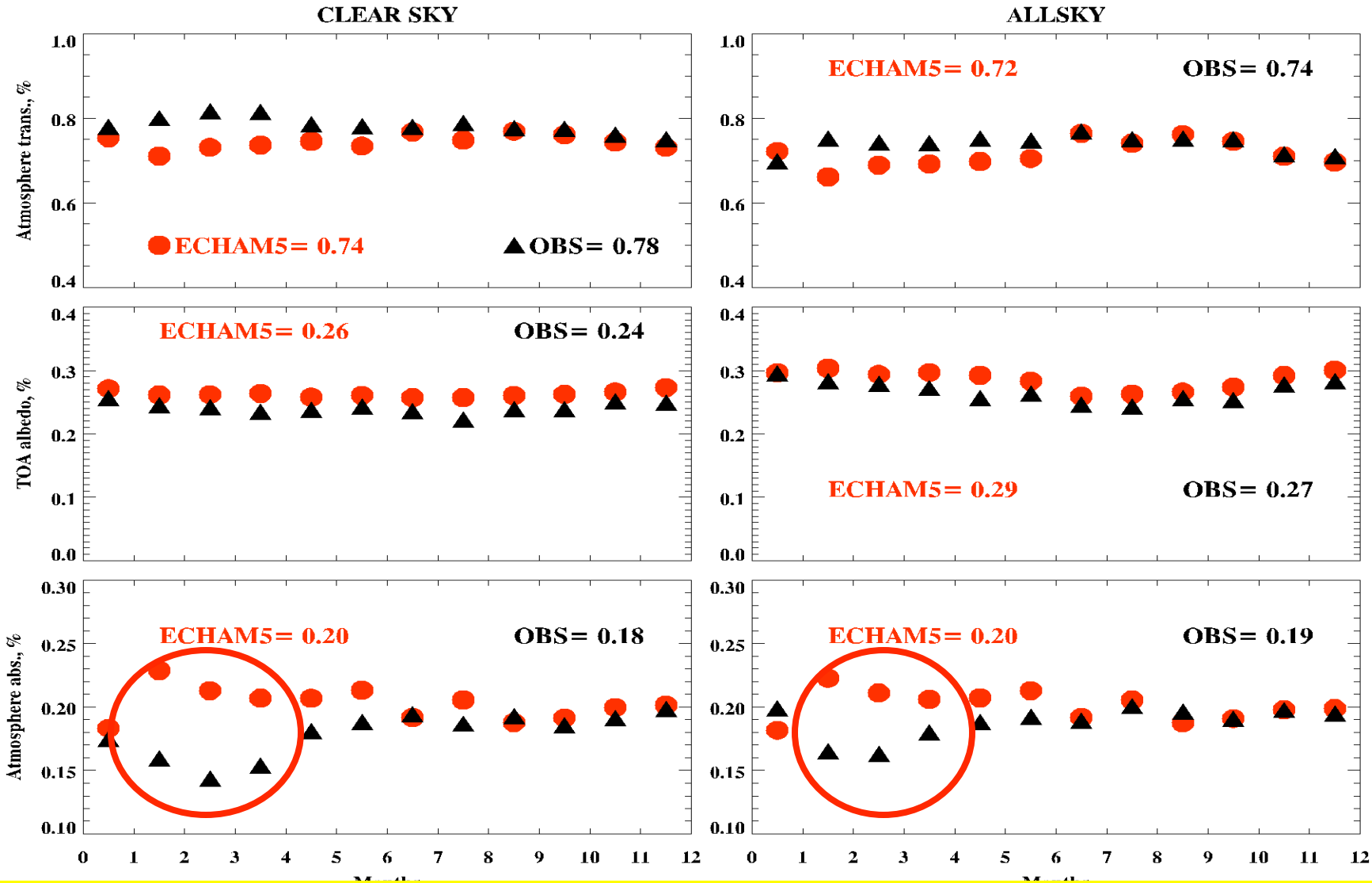
All three parameters agree within 2%

Over Grass



Clears-sky differences are 3-4% in T_{SFC} and R_{TOA}
All-sky: there are large differences for a few months

Over Desert Regions



Although their averages are close to 4%, a large difference exists during Feb-April➔ A further study is needed.

Summary

1) The ECHAN5 simulated T_{SFC}, R_{TOA} and A_{COL} correlate with CERES-derived cloud fraction very well, and agree well (1-3%) with observations.

2) However, there are relatively large differences over some regions and months. A further study is needed.

3) Under all-sky conditions, T_{SFC} is lower and R_{TOA} is higher than those under clear skies, but A_{COL} does not increase too much.


Thanks for your attention

Clear sky

Surface albedo increase

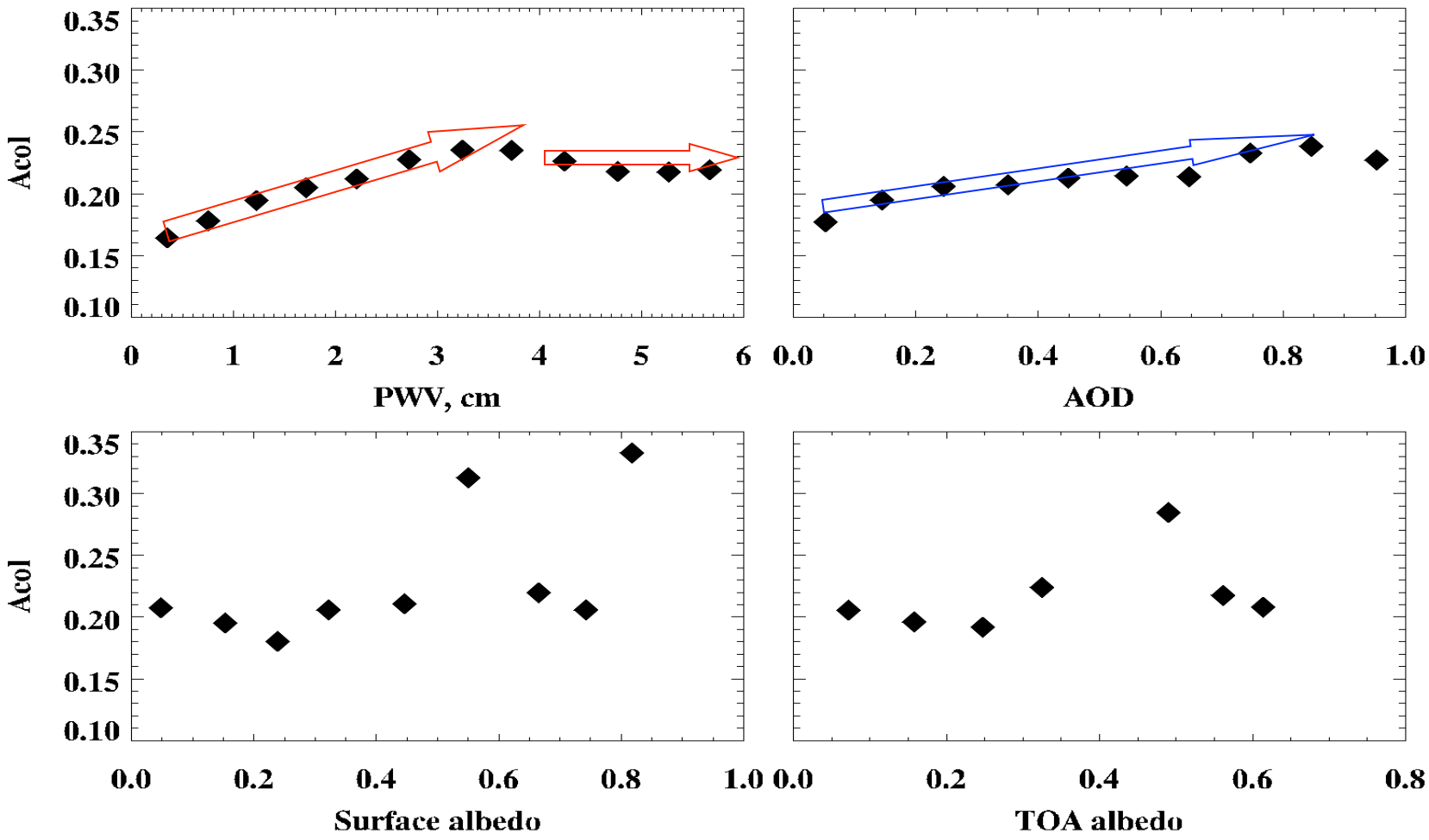
SFC types	A_{col_CRS}	A_{col}
OCEAN	0.202	0.204
Land Ocean	0.223	0.281
GRASS	0.187	0.193
DESERT	0.192	0.182
Snow/Ice Land	0.231	0.227

Regions	A_{col_CRS}	A_{col}
Tropical	0.221	0.268
Sub-tropical	0.192	0.190
Mid-latitude	0.194	0.191
Arctic	0.231	0.227

1. A_{col} values in the sub-tropical and mid-latitude are nearly the same.
2. Higher A_{col} values in tropical is mainly due to high water vapor.
3. Higher A_{col} values in Arctic is mainly due to high surface albedo.

The difference between A_{col} and A_{col_CRS} is within 0.01 except for mixed land and ocean, mainly due to BSRN observations

Sensitivity of clear-sky A_{col} to PWV, AOD, Albedo



➔A_{col} is strongly dependent on PWV up to ~3-4 cm, then saturated.
➔A_{col} also depends on AOD, but not as strong as PWV
➔A_{col} does not strongly depend on both surface and TOA albedos